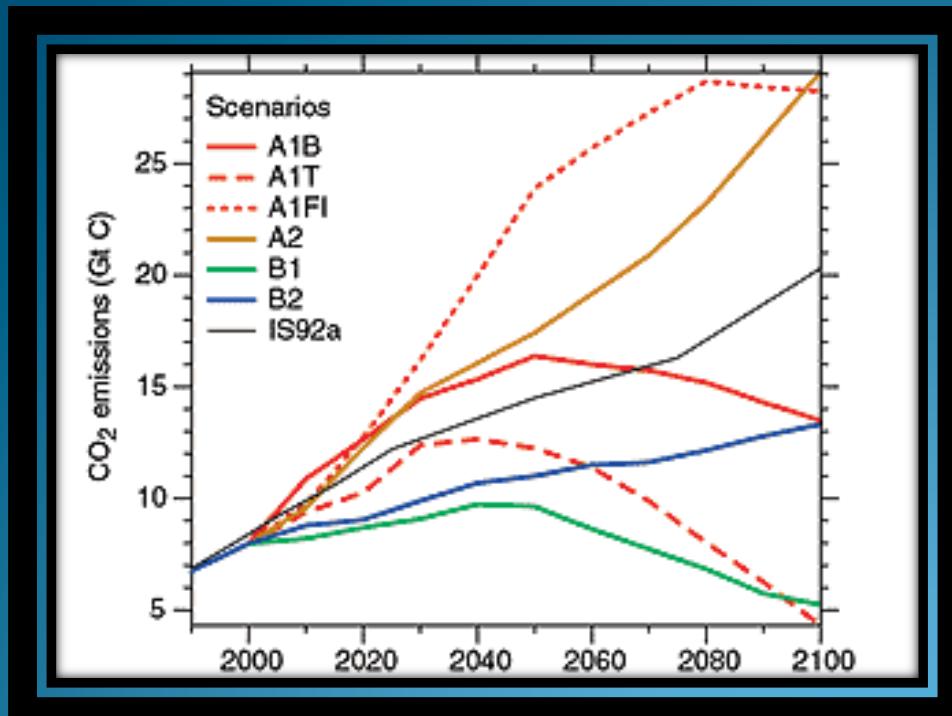


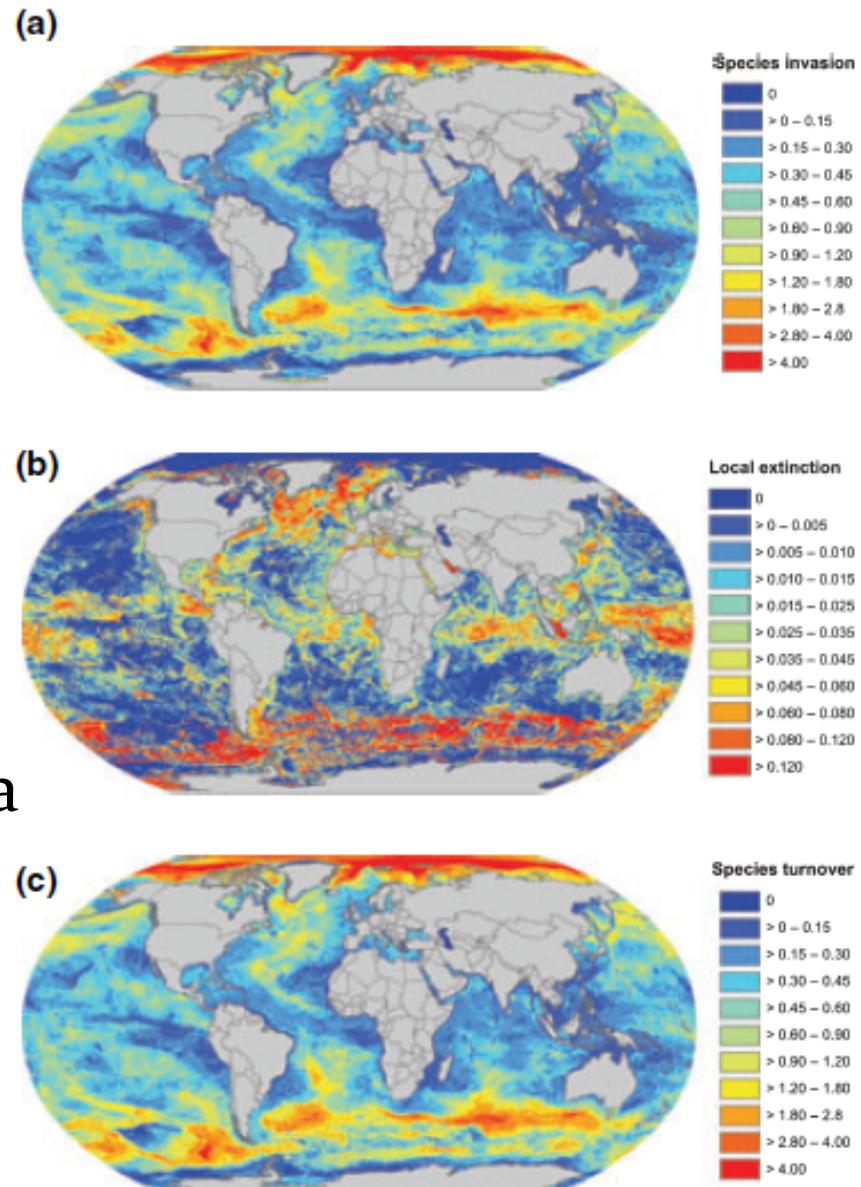
Projecting the impacts of climate change on fish, fisheries and marine ecosystems



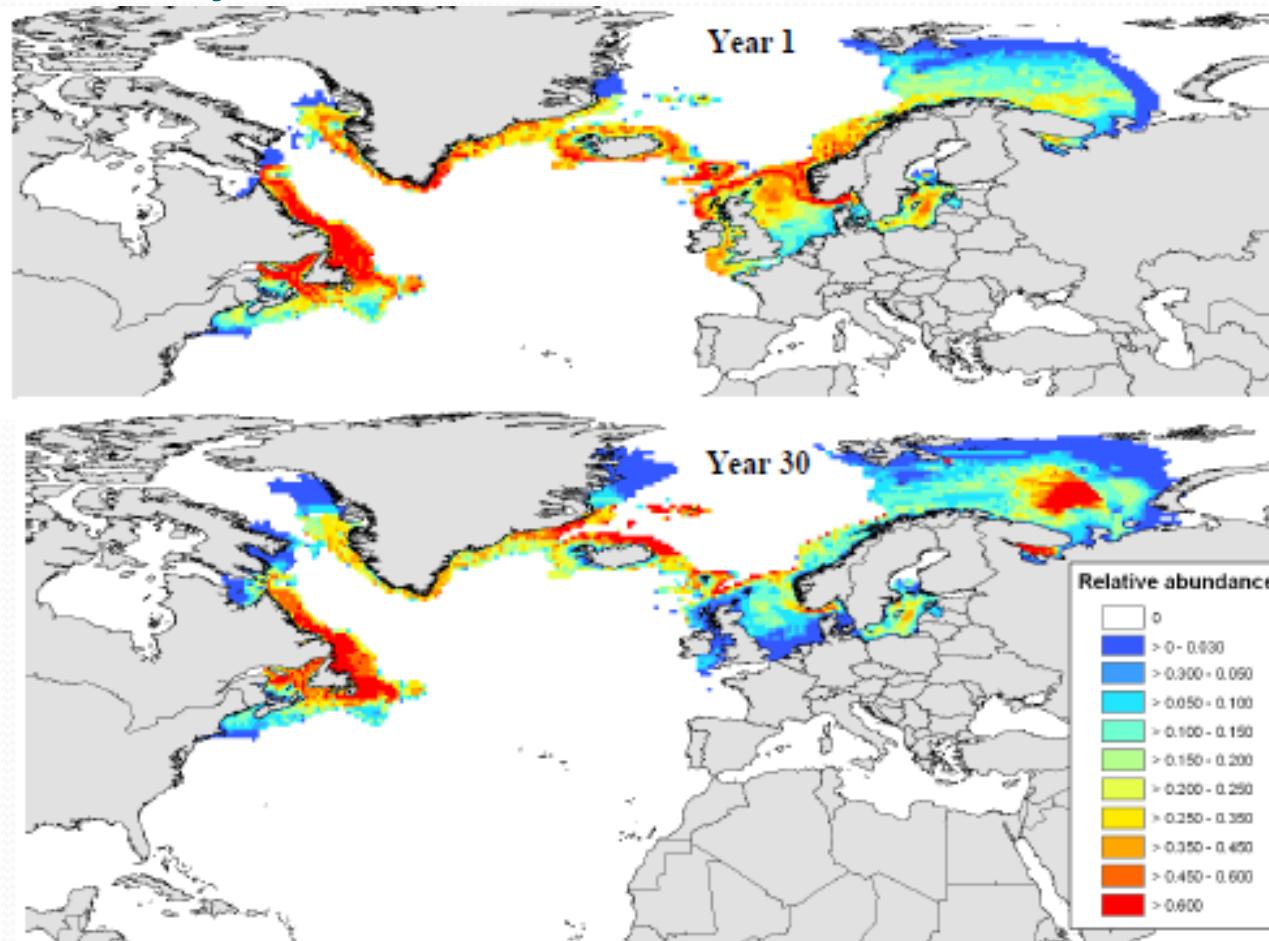
Janet Nye
Stony Brook University
December 2, 2014

Cheung's projections of changes in global biodiversity

- 1 GCM (GFDL CM 2.1)
- Simple model of population growth (logistic population growth)
- Bioclimatic envelope based on SST, salinity, sea ice cover, ocean advection, bathymetry, habitat



Cheung's projections of changes in global biodiversity-Atlantic cod

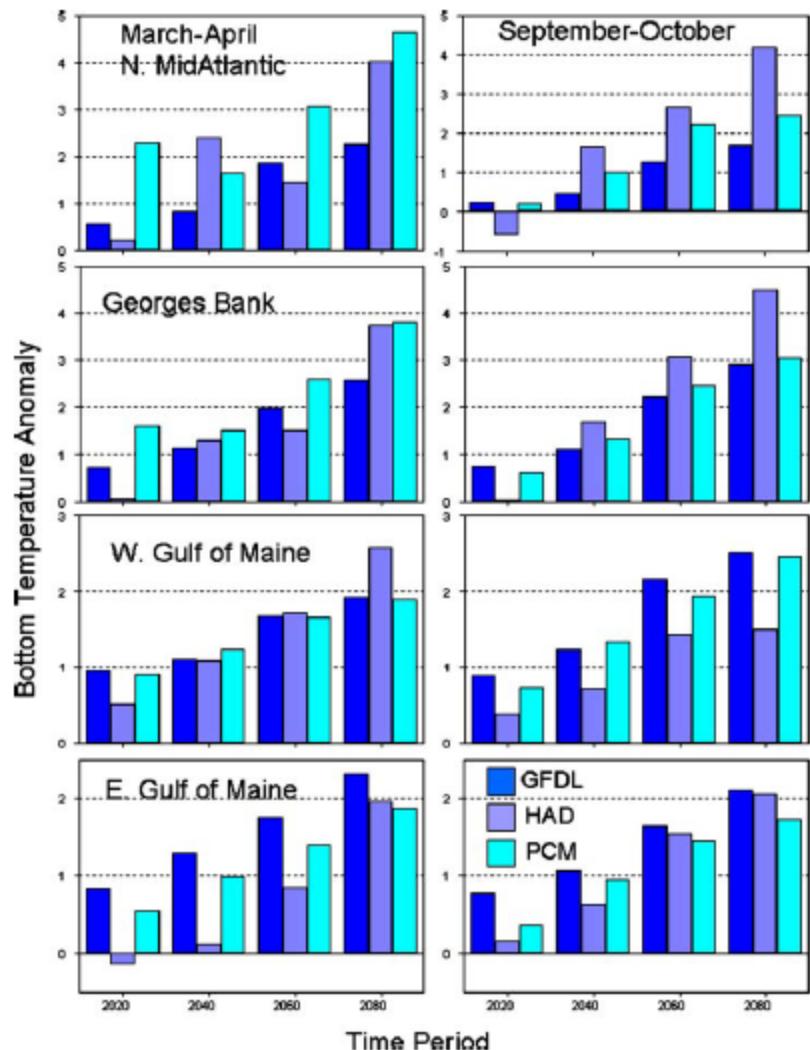


Cheung, W.W.L., Lam, V.W.Y., Pauly, D., 2008. Modelling present and climate-shifted distribution of marine fishes and invertebrates. Vancouver, B.C., Canada: Fisheries Centre Research Reports, p. 72.

Potential climate change impacts on Atlantic cod (*Gadus morhua*) off the northeastern USA.

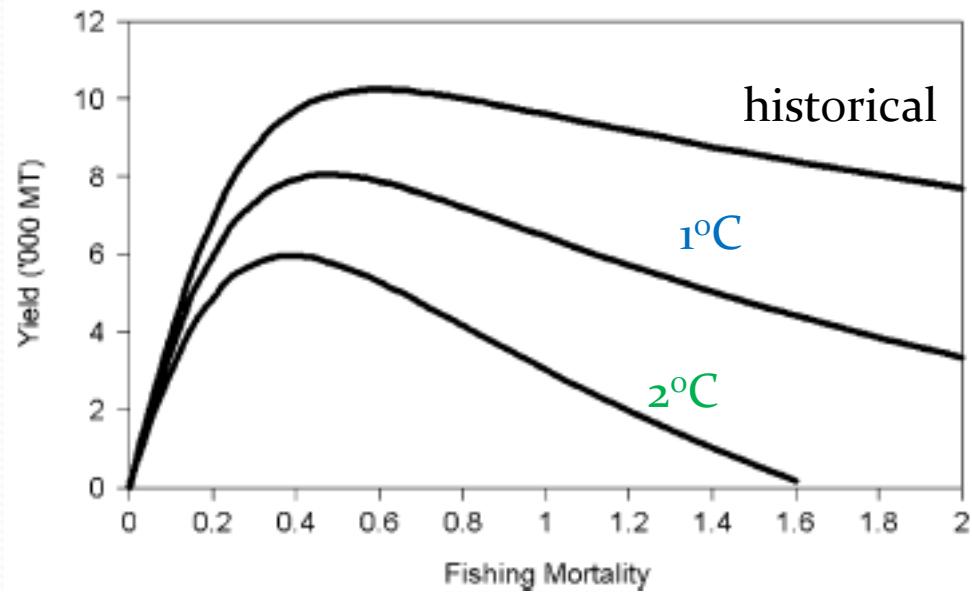
Fogarty, M. L. Incze, K. Hayhoe, D. Mountain and J. Manning. 2008.

- Three climate models examined
- Linear regression of observed data used to predict BT from SST
- SST from GCMs converted to BT for 4 regions and 2 seasons



Atlantic cod in Northeast US

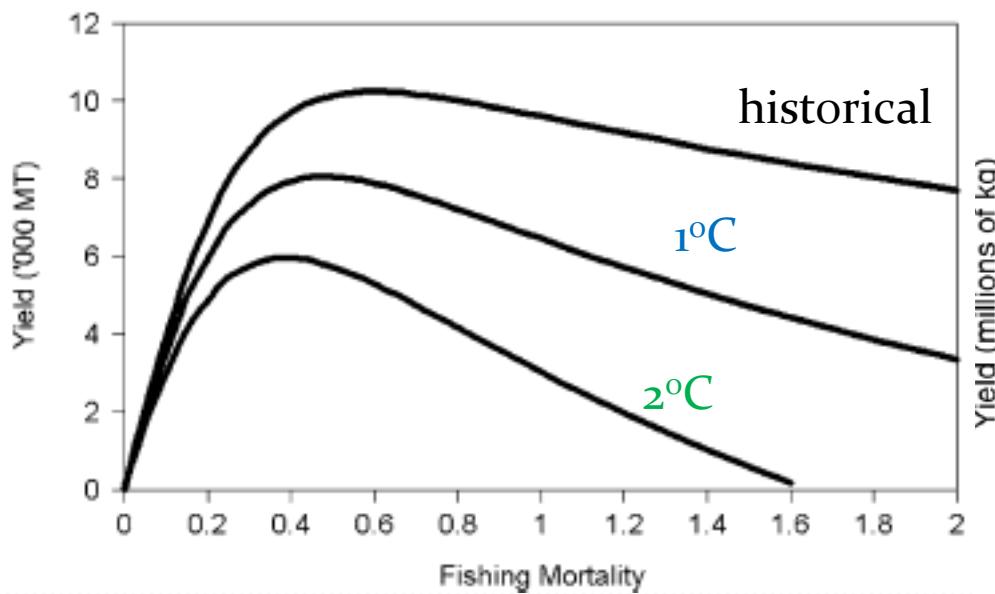
- Effect of temperature incorporated into growth and recruitment
- Predicted cod yield at three different temperatures
- Also projected change in distribution



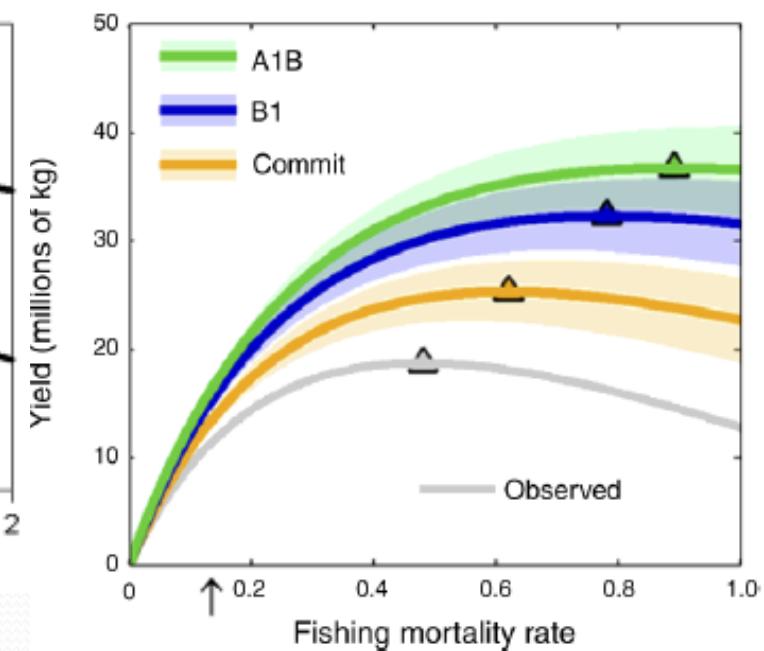
Forecasting the dynamics of a coastal fishery species using a coupled climate–population model

JONATHAN A. HARE,^{1,5} MICHAEL A. ALEXANDER,² MICHAEL J. FOGARTY,³ ERIK H. WILLIAMS,⁴ AND JAMES D. SCOTT²

Atlantic cod



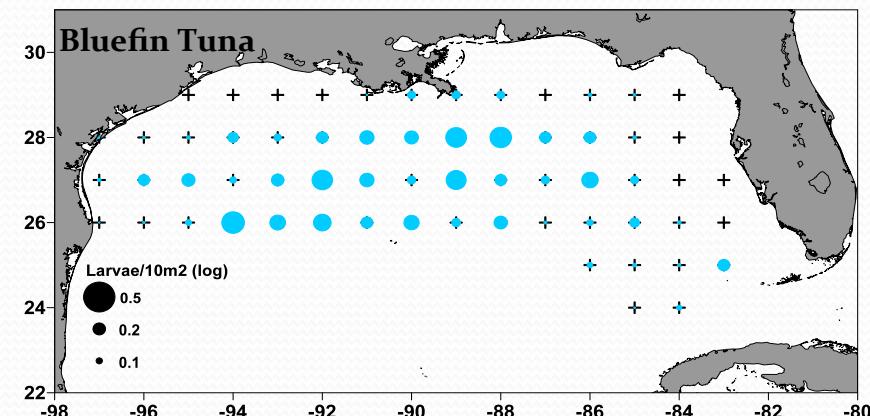
Atlantic croaker



- Fogarty et al. 2008

Distribution-based approach

- Develop habitat model and project habitat and maybe abundance
- For data poor species
- For rapid “assessment”
- Endangered Species Act applications
 - Cusk *Brosme brosme*
 - River herring (alewife and blueback herring)
- Highly migratory species
 - Bluefin tuna
 - Yellowfin and blackfin tuna
 - Skipjack tuna





Cusk (*Brosme brosme*) and climate change: assessing the threat to a candidate marine fish species under the US Endangered Species Act

Jonathan A. Hare^{1*}, John P. Manderson², Janet A. Nye³, Michael A. Alexander⁴, Peter J. Auster^{5,6}, Diane L. Borggaard⁷, Antonietta M. Capotondi⁴, Kimberly B. Damon-Randall⁷, Eric Heupel⁵, Ivan Mateo^{7†}, Loretta O'Brien⁸, David E. Richardson¹, Charles A. Stock⁹, and Sarah T. Biegel⁷

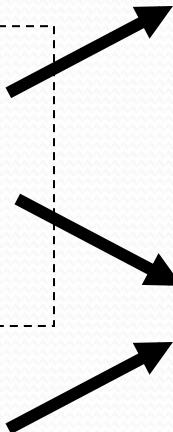
Bottom type

Static Field

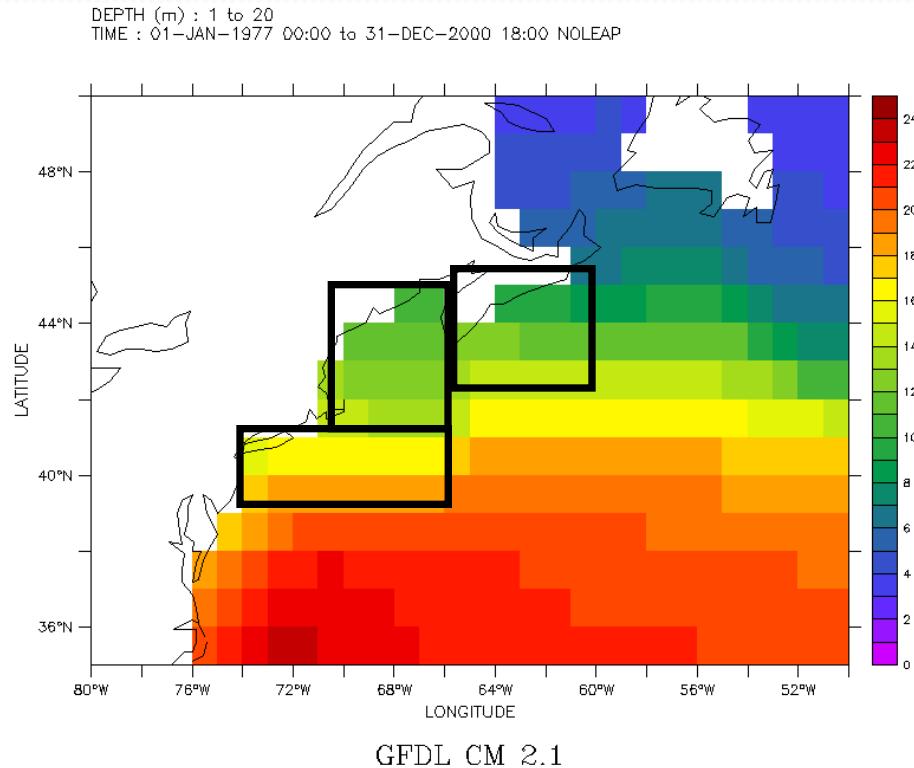
Habitat Model
(GAM)

Temperature
at depth

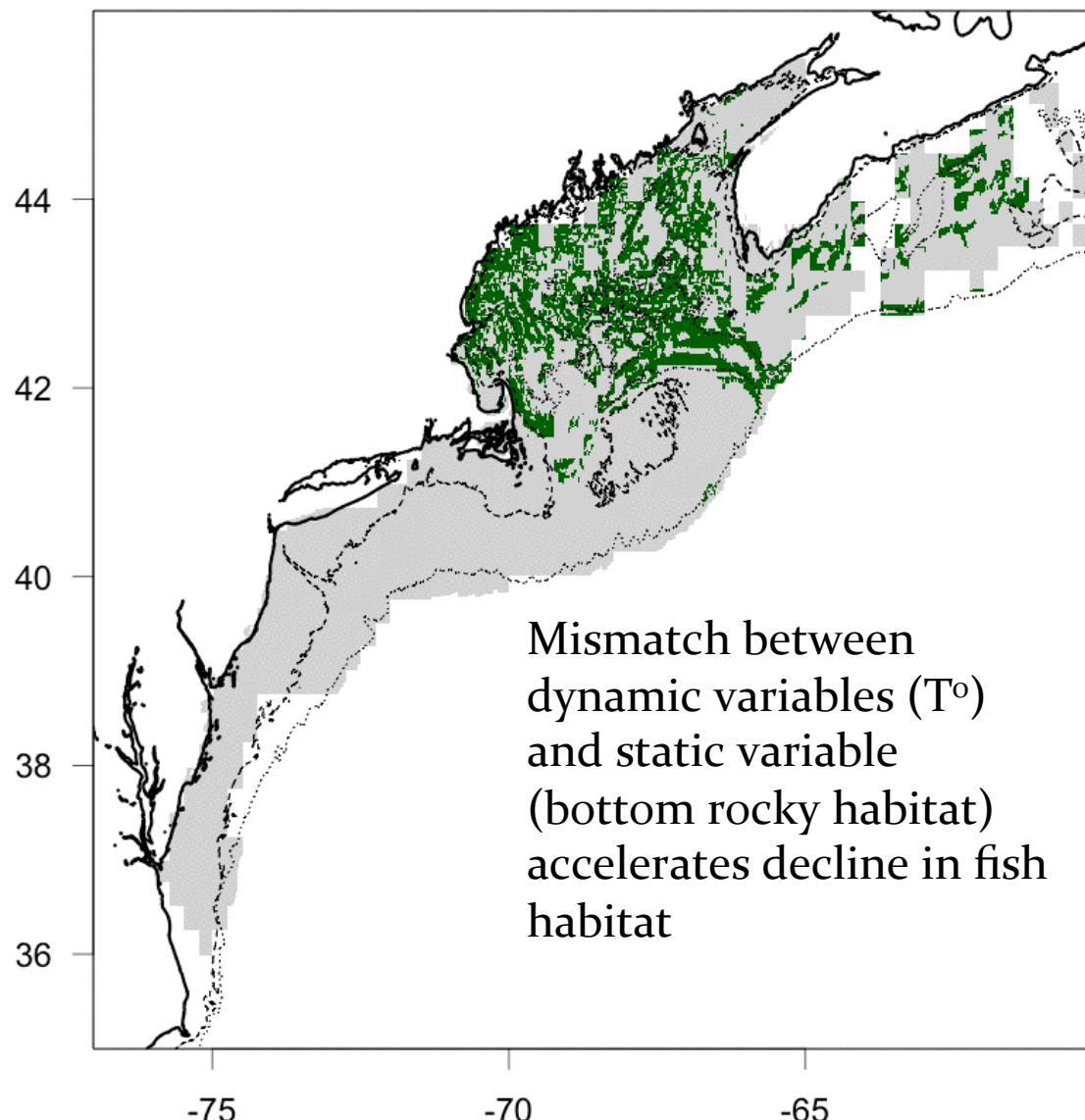
Dynamic Field



Climate Models



Potential habitat NovDec



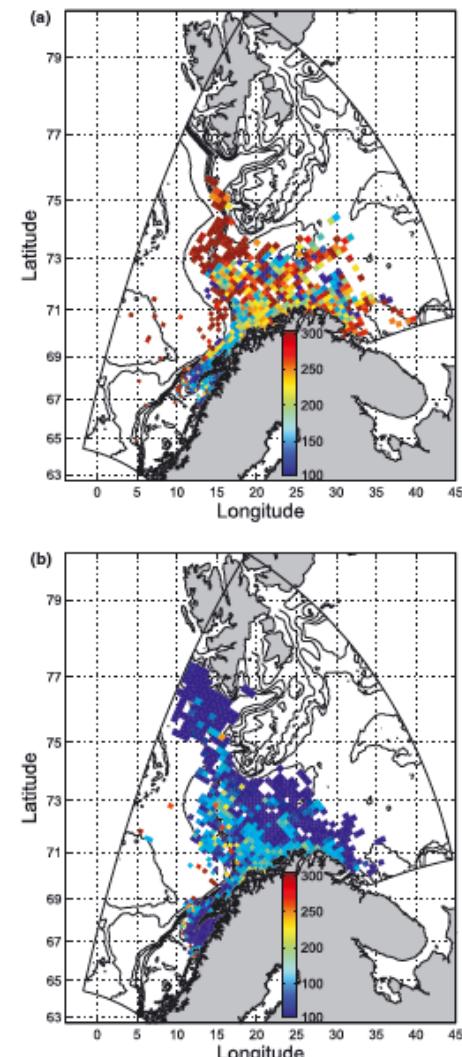
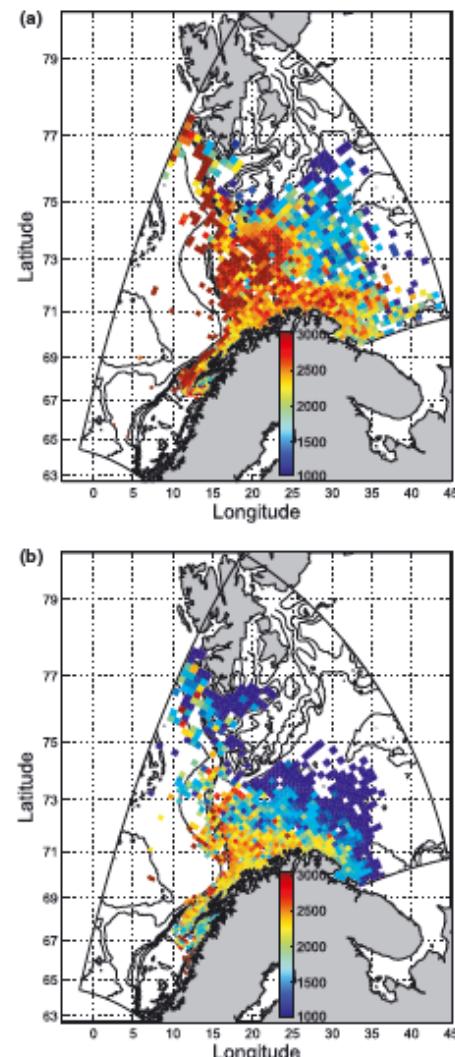
Sources of variability

| Factor | Proportion variance explained | Number of levels |
|-------------|-------------------------------|-------------------|
| Region | 0.002 | 3 (SNE, GOM, ScS) |
| Scenario | 0.052 | 3 (A2, A1B, B1) |
| Time period | 0.396 | 2 (2060, 2100) |
| Depth | 0.012 | 12 |
| Season | 0 | 6 |
| GCM | 0.183 | 7 |
| Error | 0.354 | |
| Total | 1 | |

Impacts of a reduced thermohaline circulation on transport and growth of larvae and pelagic juveniles of Arcto-Norwegian cod (*Gadus morhua*)

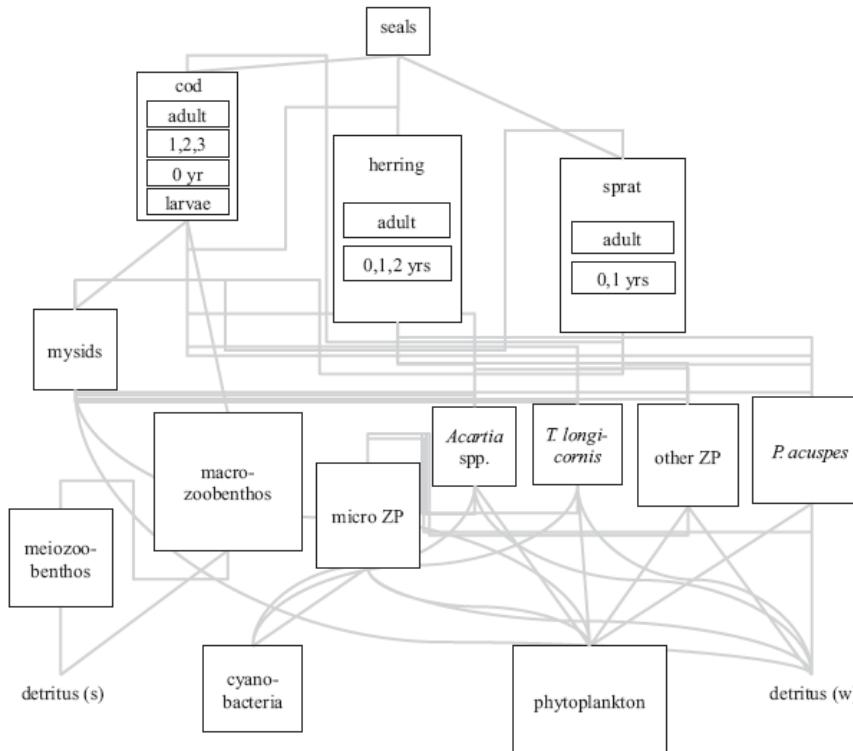
F. B. VIKEBØ,^{1,*} S. SUNDBY,² BJØRN
ÅDLANDSVIK² AND O. H. OTTERÅ³

- IBM
- THC weakened by increasing river flow threefold
- Main effects were temperature and advection
- Response was on growth, abundance and spatial distribution



Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web

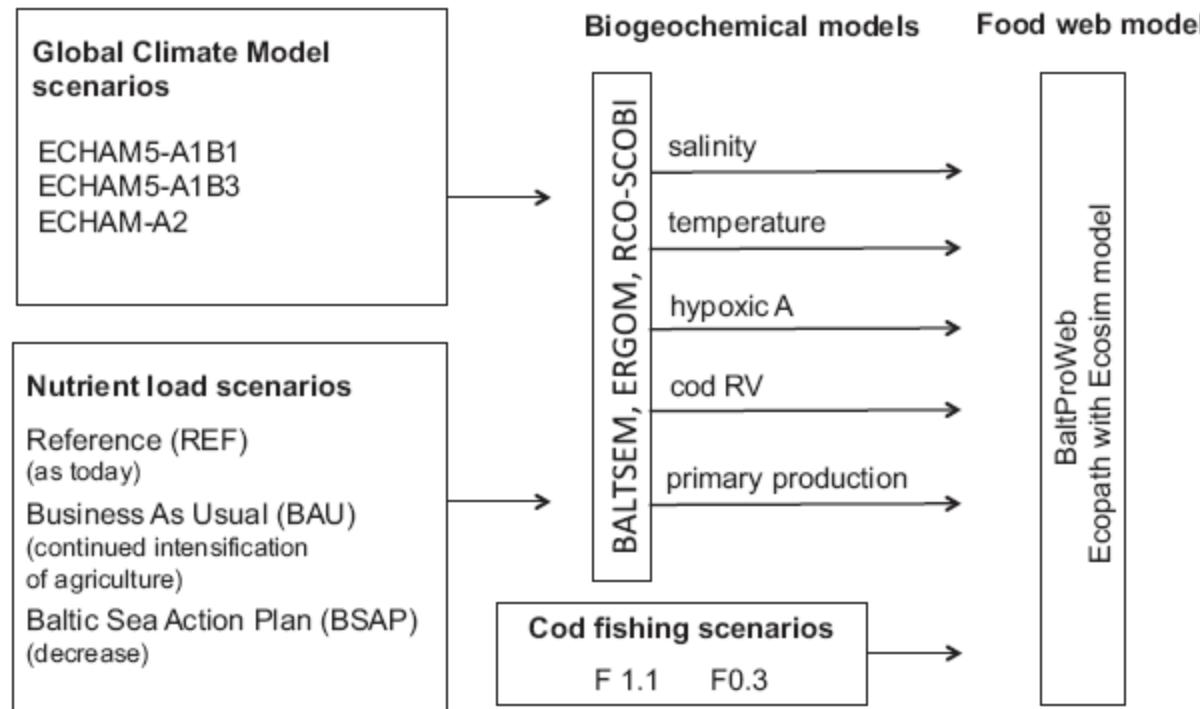
SUSA NIIRANEN*†, JOHANNA YLETYINEN*‡, MACIEJ T. TOMCZAK§, THORSTEN BLENCKNER*, OLLE HJERNE†, BRIAN R. MACKENZIE¶, BÄRBEL MÜLLER-KARULIS§, THOMAS NEUMANN|| and H. E. MARKUS MEIER**††



- Food web model
(Ecopath with Ecosim)
- Dynamical downscaling
- Multiple stressors-
nutrient runoff, fishing
and climate
- But a relatively simple
food web!

Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web

SUSA NIIRANEN*†, JOHANNA YLETYINEN*‡, MACIEJ T. TOMCZAK§, THORSTEN BLENCKNER*, OLLE HJERNE†, BRIAN R. MACKENZIE¶, BÄRBEL MÜLLER-KARULIS§, THOMAS NEUMANN|| and H. E. MARKUS MEIER**††



Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web

SUSA NIIRANEN*†, JOHANNA YLETYINEN*‡, MACIEJ T. TOMCZAK§, THORSTEN BLENCKNER*, OLLE HJERNE†, BRIAN R. MACKENZIE¶, BÄRBEL MÜLLER-KARULIS§, THOMAS NEUMANN|| and H. E. MARKUS MEIER**††

Table 3 The average biomass trends of selected groups for near (2020–2049) and far (2070–2098) future in different management scenarios for nutrient loads

| Group | 2020–2049 | | | | | | 2070–2098 | | | | | |
|------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | REF | | BAU | | BSAP | | REF | | BAU | | BSAP | |
| | $F_{1.1}$ | $F_{0.3}$ |
| Adult cod | ↓ | ↑ | ↓ | ↑ | ↓ | ↑ | ↓ | ↑ | ↓ | ↑ | ↓ | ↑ |
| Adult herring | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↑ | ↓ | ↓ | ↓ |
| Adult sprat | ↑ | — | ↑ | ↑ | ↑ | ↓ | ↑ | ↑ | ↑ | ↑ | ↑ | — |
| <i>Pseudocalanus acuspes</i> | — | ↑ | — | ↑ | ↓ | ↑ | ↓ | — | ↓ | — | ↓ | — |
| <i>Acartia</i> spp. | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| Other mesozooplankton | — | ↑ | — | ↑ | — | ↑ | ↓ | ↑ | ↓ | ↑ | ↓ | ↑ |
| Phytoplankton | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |

REF, reference; BAU, business as usual; BSAP, Baltic Sea Action Plan; for cod fishing: $F_{1.1}$ = intensive fishing, $F_{0.3}$ = recovery plan. Arrows indicate a decrease or increase in biomass from 1974–2006 (black arrow = $\pm 10\text{--}49\%$, red arrow $\pm \geq 50\%$) and ‘—’ indicates no change in biomass ($\max \pm 10\%$).

Conclusions

Focus has been on temperature

- Incorporate additional variables (salinity, advection) or use Earth System models to look at stratification, plankton assemblages

Focus on means

- Extremes may cause regime shifts that are ultimately more important in structuring ecosystems than changes in mean

The issue of scale

- Need finer scale models and/or dynamical downscaling
- Use large-scale oceanographic features that are well-represented in GCMs and that have been shown to structure ecosystems

Move beyond single species → ecosystem models

Use a multi-model inference approach

| | Species | Downscale method | Scenario | Geographical area | # GCMs | Climate and stressor variables | Bio/Ecological model |
|-------------------------|---------------------|------------------|-----------------|----------------------------|--------|---|------------------------------|
| Cheung et al. 2008 | Many | None | Commit, B1, A1B | Global | 1 | SST + 6 others | Logistic pop. growth |
| Fogarty et al. 2008 | Atlantic cod | Δ | A1Fi, A2, B1 | Northeast US coast | 4 | T° | Growth, SR, distribution |
| Hare et al. 2010 | Atlantic croaker | Δ | Commit, B1, A1B | Northeast US | 14 | T° | SR, distribution |
| Hare et al. 2012a | Gray snapper | Δ | Commit, B1, A1B | Southeast US coast | 14 | T° | Habitat |
| Hare et al. 2012b | Cusk | Δ | B1, A1B, A2 | Northeast US coast | 7 | T° (and bottom type) | Habitat |
| Lynch et al. in press | River herring | Δ | B1, A1B, A2 | Northeast US coast | 7 | T° | Habitat |
| Vikebo et al. 2007 | Atlantic cod | Δ | THC | Arctic/Nordic Sea | 1 | Reduced THC, increase river runoff | Individual based model (IBM) |
| Muhling et al. 2011 | 3 tuna species | Δ (weighted) | A1B | Gulf of Mexico | 20 | T° | Habitat |
| Mackenzie et al. 2012 | Sprat | Dynamical | A1B | Baltic Sea | 1 + 1 | T° | Age structured model, SR |
| Diamond et al. 2014 | Atlantic croaker | Δ | A2,A1B,B1 | Southeast US coast | 3 | T°, hypoxia, salinity, sea level rise and ocean circulation | Nonlinear matrix model |
| Kristiansen et al. 2014 | Atlantic cod | ESM | | 5 stocks in North Atlantic | 1 | T°, stratification, zooplankton size class | Individual based model (IBM) |
| Niiranen et al. 2013 | Baltic sea food web | Dynamical | A1B, A2 | Baltic Sea | 1 + 3 | To, salinity, hypoxia, fishing, primary prod. | Ecopath w/ Ecosim |